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*Sir:*

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### TITLE OF INVENTION (280 Characters Max.)

TERMITE ACOUSTIC DETECTION, CONTROL, AND DAMAGE EVALUATION

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Respectfully Submitted,

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| | Additional inventors are being named on separately numbered sheets attached hereto. |
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APPLICATION FOR

UNITED STATES LETTERS PATENT

of

Peter Peng LEE

for

**TERMITE ACOUSTIC DETECTION,
CONTROL, AND DAMAGE EVALUATION**

<u>Attorney Docket No.</u>: BEU/Umiss/lee

## TERMITE ACOUSTIC DETECTION, CONTROL, AND DAMAGE EVALUATION

## BACKGROUND OF THE INVENTION

1.  Field of the Invention

5   This invention relates to the fields of termite detection, control, and damage evaluation.

More particularly, the invention relates to the following methods, systems, and devices for detecting, controlling, and accumulating data concerning termites, and

10  for evaluating the extent of termite damage:

(a)  Termite Detection

- A system including an acoustic sensor for detecting the presence of termites concealed in a structure;

- A system including a passive laser doppler vibrometer for detecting the presence of termites concealed in a structure;

- A system including an acoustic sensor and a thermal imaging camera for detecting the presence of termites concealed in a structure;

- Methods utilizing the above-described systems for detecting termites concealed in a structure, and for evaluating damage caused by the termites;

(b) Damage Evaluation

- A system including an active laser doppler vibrometer for determining the extent of concealed structural damage caused by termites.

(c) Termite Control

- A system and method of modifying termite behavior through use of acoustic vibrations.

(d) Data Accumulation

- Methods utilizing the above-described systems for collecting, aggregating, and making available data on termites;

- A central database of termite information.

2. Description of Related Art

Termites are the most destructive and economically important insect pests of wood, root, grass, or processed cellulose material. Termites attack wood throughout most

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of the world, with the exception of the hard freeze areas. They are one of the most common insects and therefore cause the most destruction. There are close to 50 species of termites in the United States, the vast majority of loss being caused by subterranean species. All termites are social insects. They live in colonies that can number over 1 million individuals, each member accomplishing tasks that in concert contribute to a robust adaptable and productive society. The reproductive termites are physiologically specialized for mass production of offspring. In many species of termites, colonies have mechanisms for replacing or augmenting the reproductive staff as the colony grows and matures.

In 1999, an estimate done by renowned termite research scientist Dr. Nan-Yao Su at the University of Florida, resulted in a cost of $2.2 billion in termite control alone. The $2.2 billion control cost did not include the cost of repair to damaged buildings. A limited survey in the city of New Orleans suggested a 4:1 ratio for repair versus control cost for Formosan Subterranean termites (E. Bordes, New Orleans Mosquito and Termite Control Board). If this ratio is adopted, the total annual economic impact of subterranean termite as a whole in the United States could amount to $11 billion in 1999.

The rising cost of termite control is attributed to several factors. Poorly designed slab-on-ground construction and greater use of concrete and masonry terraces adjacent to foundation walls favor termite attacks

5    and result in increased damage to building. Repairs, remodeling, and landscaping made without regard to termite prevention and control often leading to termite problems, and impair the effectiveness of any prior chemical treatment. Only a small portion of the approximately 80

10   million single-family dwellings in the US have been treated to control termites. Few homes are treated during construction, although this is the best and most economical way of treatment. It is often more difficult and costly to apply effective control measures after a building has

15   become infested with termites.

Because live termites and their damage in wood is usually not evident, the inspector focuses on more indirect and subtle external signs of an infestation including foraging tubes, nest matrix, moisture stain, and feed

20   pallets expelled from termite colonies. The inspector may also tap the wood surface to detect underlying gallery voids. When a wood member suspected of containing termites is located, the inspector uses a sharp probe such as a screwdriver to break the wood surface and locate wood

25   galleries and live termites. The confirmation of an active

infestation, therefore, requires some localized damage to the wood. When termites are exposed in this manner, the destruction induces termites to retreat from the disturbed area and may reduce the effectiveness of a subsequent

5    localized treatment. Commercial demand for a dependable, non-destructive, and non-subjective method to detect termites has spawned a number of alternatives to visual inspection. However, none of these techniques have fully satisfied the non-destructive and non-subjective

10   requirements.

The prior non-destructive termite detection techniques fall into three general categories:

A. Sensors that detect destruction of a baited sample or entry of termites into a baited trap

15       by, for example, inclusion of circuit elements designed to be destroyed as the sample is destroyed, thereby breaking a circuit, as disclosed in U.S. Patent Nos. 6,052,066, 5,815,090; 5,592,774; activation of a switch by

20       movement of a mechanical element in response to sample destruction, as disclosed in U.S. Patent No. 5,571,967; mechanical vibrations induced in the sample as the sample is consumed, as disclosed in U.S. Patent No. 5,571,967 (col. 14,

25       line 38 to col. 15, line 42) and Japanese Patent

Publication No. H7-255344 (cited in col. 2, lines 22-38 of U.S. Patent No. 5,877,422); or penetration of a film across the entrance to a baited trap, as disclosed in U.S. Patent No. 5,877,422.

B.  Sensors that detect the presence of gases emitted by termites, as disclosed in U.S. Patent No. 6,150,944;

C.  Acoustic sensors that operate at high frequencies to avoid interference from background vibrations such as passing cars and other insects, as disclosed in U.S. Patent No. 4,809,554 (see col. 2, lines 20-38, disclosing use of ultrasonic frequencies in the 40,000 Hz range); and Japanese Unexamined Patent Publication No. H4-143837 (also cited in col. 2, lines 22-38 of U.S. Patent No. 5,877,422: detection of frequencies that exceed a threshold which excludes background frequencies); and

D.  Infrared sensors.

The various detection methods in category A are useful for detecting the presence of termites in the vicinity of a structure, but cannot be used to locate precise areas of termite infestation in concealed areas within the structure. Once it has been determined that termites are

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present in the vicinity of the structure, the only way to determine the actual locations of termites within the structure is to remove portions of the structure.

The detection methods in category B eliminate the need
5   to use bait to attract the termites, and in theory can signal the actual locations of the termites, but the sensors must be placed within the walls of a structure, limiting their applicability.

The high frequency or ultrasonic acoustic sensors of
10  category C, on the other hand, offer the advantage that they can be placed on the exterior of structural walls, rather than within the walls.     However, the high frequencies are difficult to detect through walls and other concealing structures, and fail to take into account the
15  full range of termite noises, which fall primarily in the range of 100 Hz to 15 kHz.

Alternative to ultrasonic acoustic sensors are sensors (or electronic stethoscopes) arranged to detect acoustic signals and process them so that can be listened to by a
20  trained operator, or connected to a spectrum analyzer arranged to generate a plot of signals in the frequency domain, which can then be interpreted by the operator. This method requires a high degree of operator skill and,

in addition, utilizes a relatively narrow frequency range. For example, U.S. Patent No. 4,895,025, specifies a frequency range of 1462.5 Hz to 3337.5 Hz.

It has also been proposed to use infrared sensors to detect the surface temperature differences indicative of termite infestations. However, this is relatively non-specific method, yielding numerous false positives since there are many sources of temperature differences in a typical structure. As a result, detection of termites using infrared sensors still requires destruction of walls to verify results, and to more specifically locate the actual termite infestations. Furthermore, use of infrared sensing for detection of termites also requires a relatively high degree of operator skill, training, and judgement which adds time and cost to its use.

Of the above termite detection methods, acoustic detection offers the best combination of accuracy and lack of destruction. However, such methods generally do not take into account the full range of termite sounds, as explained above, and further are restricted to highly localized detection, necessitating the taking of many samples or data points, requiring an inordinate amount of time or number of sensors to completely inspect a structure if all potential locations of termite infestation are to be

monitored. As a result, the previously proposed methods have not seen commercial implementation despite the long-felt need for such non-destructive detection.

The one reference that discloses detection of termite sounds in the 100 Hz to 15 kHz range characteristic of termite "knocking" sounds, which happens to be the range used by the present invention, is U.S. Patent No. 4,941,356 (col. 2, lines 47-64). However, this patent only provides a very general method of termite detection by correlating sounds in "the frequency range form [*sic.*] 0.01 mHz to 150 kHz, preferably from 100 Hz to 15 kHz" and fails to disclose specific apparatus, algorithms, or noise patterns to support the general method. The present invention also operates in the 100 Hz to 15 kHz range, but provides a specific acoustic detection method.

In addition to failing to conveniently and reliably detect termites, the above methods do not provide a non-destructive way of assessing damage once termites are found, or of eradicating the termites. With all of the above methods, the only way to determine the extent of damage is to visually observe the damage, which necessitates tearing out walls or otherwise conducting destructive probes to access the portions of the structure where termite infestations typically occur.

Moreover, despite advances in non-destructive termite detection, the only reliable methods of eliminating the termites, once detected, continue to involve the application of toxic or environmentally destructive 5 chemicals (or possibly, extreme temperature). To date, effective non-destructive methods of evaluating termite damage, and of eliminating the termites without using toxic chemicals, have yet to be proposed.

## SUMMARY OF THE INVENTION

10 It is accordingly a first objective of the invention to provide a non-destructive and yet reliable method and apparatus for detecting the presence of termites, evaluating structural damage, and affecting the behavior of termites in a way that hastens their elimination without 15 the need for large scale application of toxic chemicals.

It is a second objective of the invention to provide a termite detection method that utilizes non-destructive acoustic detection, that is carried out in the full termite noise frequency range of 100 Hz to 15 kHz, and that does 20 not require on-site monitoring or interpretation of the acoustic detection results by a human operator.

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It is a third objective of the invention to provide a termite detection method that utilizes non-destructive acoustic detection and yet that minimizes the number of acoustic sensors, sample sites, and time required to
5   inspect a structure.

It is a fourth objective of the invention to provide a non-destructive acoustic method and system for evaluating structural damage caused by termites.

It is a fifth objective of the invention to provide a
10  method of altering the behavior of termites that hastens their destruction, utilizing sounds to attract or repel the termites.

It is a sixth objective of the invention to provide a central database of termite information, and to make the
15  information available to appropriate entities and individuals.

These objectives are achieved, in accordance with the principles of a first preferred embodiment of the invention, by providing a method and apparatus for
20  detecting termites by monitoring and recording sounds transmitted through structures in the full 100 Hz to 15 kHz

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range of termite noise frequencies, and by using pattern matching or recognition to analyze the sounds.

In one implementation of the preferred embodiment, the invention involves placement of accelerometers on walls and other exposed surfaces of a structure, such as roof trusses, communicating the signals output by the accelerometers to a centrally located computing device, and analyzing the signals, preferably in the time domain, for patterns characteristic of termites or other wood eating insects.

In an alternative implementation of the preferred embodiment, the invention involves use of a passive laser doppler vibrometer to detect vibration of an unexcited wall or other concealing structure.

The overall goal of the acoustic detection system is to detect termite infestation in buildings and trees accurately and as early as possible. Early and accurate detection of an infestation reduces damage and the amount of insecticide use. By using acoustic detection, little to no damage to buildings or trees occurs during the inspection process, therefore reducing the amount of money spent by the homeowner on repair work as well as reducing the risk of a lawsuit by the homeowner.

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While one particularly preferred sensor is the accelerometer, which has the advantages of mostly picking up structure-borne acoustic signals and very little or no airborne acoustic signals, of covering the whole termite activities frequency range (below 15 kilohertz), and of being relatively inexpensive and durable, those skilled in the art will appreciate that it is also possible to use other types of acoustic sensors so long as they are relatively insensitive to airborne acoustic signals, are sufficiently sensitive to detect termite noise levels, and cover an appropriate frequency range.

Because different species of termites might have different activity sounds, the preferred embodiment of the invention further provides for various species of termite activity sounds need to be pre-recorded, characterized, and stored in a library, which serves as a database to be compared with the newly detected termite activity sounds. When the comparison achieves a certain pre-determined degree of similarity, a "Termite Detected" message is issued. Otherwise a "No Termite Detected" message is issued. This acoustic pattern recognition system not only can be used to detect and identify termite infestation but can also be used to detect and identify other insect infestations by simply replacing the termite database

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library with other appropriate insect database libraries of interest.

While the invention is not limited to a particular pattern matching algorithm, there are various techniques
5 that are capable of identifying the insect acoustic signal. For example, the cross-correlation algorithm, although not the fastest, has shown good consistency and accuracy. Cross-Correlation works best when the insect signal is louder than the background noise. Other techniques may be
10 used to extract acoustic signals that are embedded in the background noise level.

In accordance with another aspect of the preferred embodiment of the invention, the acoustic detection method and system are combined with an infrared detection system.
15 Infrared detection has the advantage of covering a larger area than acoustic detection and, although less specific or accurate than acoustic detection, provides efficient screening and a convenient way of scanning the structure for potential infestations in order to guide placement of
20 acoustic sensors in order to carry out more specific tests with the acoustic sensors.

Infrared detection works because termites require a high percentage of humidity in their living environment.

Moisture brought in by the termites produce a temperature change in the wall, which can be detected by the infrared thermal camera. The use of infrared detection has the advantage of identifying potential infestation sites, which

5    can then be positively identified using the above-described acoustic pattern recognition system to positively identify the termite infestation. This combination of infrared and acoustic inspection couples a quicker but low-specificity screening technique for speed with a high specificity,

10   slower technique for accuracy, and is a significant improvement in the art having important commercial implications.

According to yet another aspect of the preferred embodiment of the invention, in order to further improve

15   the accuracy of initial detection using the infrared camera, the system and method of the invention may also include target recognition software to pin point the suspicious area on behalf of the user. This target recognition software can be achieved by simply

20   distinguishing the object's surface temperature and identifying those areas with the same temperature.

The structural damage evaluation objective of the invention are also achieved by using non-destructive acoustic testing methods and apparatus. In particular,

this aspect of the invention involves use of an active laser doppler vibrometer to detect acoustic patterns following acoustic excitation of the structure being evaluated, using apparatus and techniques similar to those

5 described in detail in U.S. Patent No. 6,081,481, herein incorporated by reference.

A still further aspect of the preferred embodiment of the invention is modification of the behavior of detected termites using acoustic signals. The goal of such

10 "behavior modification" is to either repel the termites, induce them to enter a trap where they can be destroyed, or otherwise cause the termites to behave in a self-destructive manner.

The acoustic behavior modification aspect of the

15 preferred embodiment is based on discoveries relating to the manner in which termites recognize and react to sounds, and in particular their ability to sense subtle vibrations in a structure by means of the sensory hairs that are found all over the body parts of termites. These sensory hairs

20 vary in size from a few microns up to hundreds of microns. Because these sensory hairs on the legs are directly associated with the nervous system, when the sensory hairs on the termite's legs come in contact with a substrate

surface, the termite is capable of picking up and responding to very minute substrate vibrations.

Preliminarily tests have shown that when a termite was secured to a very small and light weight fixture with two micro electrodes, one inserted into the nervous system right next to the base of one of the six legs, and the other inserted into another part of the body, the two micro electrodes formed a closed electrical circuit, and that when acoustical vibrations were introduced to the termite, certain physical and nervous responses were invoked. The nervous responses were in the form of electrical signals, which were clearly picked up by the micro electrodes, while the physical responses were displayed through the aid of a microscope and CCD video camera.

Armed with this understanding of acoustic responses, examples of which are illustrated in a sound recording authored by the present inventor (copyright registration number ---------) and published by the U.S. Department of Agriculture on Monday, May 14, the skilled artisan can, in principle, use the acoustic signals to alter the termite's behavior, creating a non-chemical acoustical barrier to keep termites out of a building, make chemical bait more attractive to termites, or possibly even trigger a self-destruct process in the termite colonies.

Finally, according to yet another aspect of the preferred embodiment of the invention, the sounds and location data taken at each inspection site using the above-summarized methods and apparatus, as well as data

5 provided by other available sources, may be provided to a central operations unit for use in building a central database of termite information. The central operations unit may operate on a nationwide or even worldwide basis, and serves as a facility of data communications, data

10 acquisition, data analysis, maintenance of sound libraries, continuous updating of sound library references, aggregation of recognition results, and aggregation of inspection results. The accumulated data may be made available to entities interested in termite presence,

15 behavior, movements, and trends, or in termite infestation and damage to structures, for access by structure, species, or geography, thereby providing an invaluable termite information resource. No such centralized resource is currently available.

20 **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a schematic illustration of a termite detection system assembled in accordance with the principles of a preferred embodiment of the invention (and

which may also be adapted to record termite sounds in order to create a library of such sounds).

Fig. 2 is a schematic illustration of an experimental setup for measuring termite response to acoustical

5   vibration.

Figs. 3-8 are frequency and time domain plots of termite sounds recorded using the setup of Fig. 1.

Fig. 9 is a schematic diagram of a system for non-destructively evaluating structural damage in accordance

10   with the principles of the preferred embodiment of the invention.

Figs. 10 and 11 are respective photographs of a piece of undamaged wood and a piece of termite-damaged wood.

Figs. 12 and 13 are plots obtained by using modal

15   analysis of the respective pieces of wood illustrated in Figs. 10 and 11.

Figs. 14-17 are plots, intended to illustrate the behavioral modification aspect of the invention, of termite response to various stimuli.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As schematically illustrated in Fig. 1, the preferred embodiment of the invention includes a thermal imaging camera 1 for performing a preliminary scan of a structure in order to locate potential termite infestations 3. Acoustic detectors 11 are positioned on walls of the structure adjacent the potentially infested locations, and the outputs of detectors 11 are supplied to a controller 12, which in turn is connected to an on-site notebook or laptop computer 13, via a wireless communication device 14 such as a personal digital assistant or web-enabled telephone to a centrally located computer 16, or directly to the central computer 16, for analyzing the detected noises. On-site computer 13 and central computer 16 each includes a respective library 14,17 of termite noises for comparison with the detected noises, as described below.

Thermal imaging camera 1 may be any of a number of commercially available infrared cameras, conventionally used by structural engineers, police, and military. In order to improve the accuracy by which the camera 1 detects potential areas of termite infestation, the thermal imaging camera may further include target recognition software, such as matched filtering software which compares the frequency spectrum of a thermal image with frequency

spectra of reference images, thereby reducing the level of skill required of the camera operator. Acoustic sensors 11, on the other hand, are preferably in the form of accelerometers, which are designed to sense vibrations in a structure while generally excluding air-borne vibrations, or laser doppler vibrometer devices, both of which are also commercially available, an example of the latter being illustrated in U.S. Patent No. 6,081,481, and an example of the former being illustrated in Fig. 2. Unlike the laser doppler vibrometer device disclosed in the patent, there is no need to induced acoustic vibrations in the area being tested since the termites generate their own noise which can be conveniently analyzed by the vibrometer, and thus the termite detection vibrometer of this embodiment is referred to herein as a passive laser detection vibrometer.

As illustrated in Fig. 1, controller 12 includes a low noise amplifier, a bandpass filter, and an analog-to-digital converter. The bandpass filter preferably has a passband, for most species of termites, or 100 Hz to 15 kHz. It will of course be appreciated by those skilled in the art that controller 12 may be a separate unit or may be included, in whole or in part, in the acoustic sensors or in the analyzer or computer. For example, instead of digitizing the sensor outputs before transmission to

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computer 13, the sensor outputs may be supplied as an analog input to the sound card of computer 13.

The termite sounds library is made up of a compilation of numerous termite sound recordings in different settings, substrates, and conditions over years.  In this regard, the system of Fig. 1 may be used as an experimental setup to capture recordings of termite noises in one setting that can be used as reference patterns for comparison with actual detected noise patterns.  Different species of termites might have different activity sounds, and the sounds made might vary with the type of wood in the structure and other conditions.  Therefore, various species of termite activity sounds, possibly under varied conditions, need to be pre-recorded, characterized, and stored in a library accessible by computers 13 or 16.  The resulting library of different species of termite activity sounds  serves as a database to be compared with the newly detected termite activity sounds.  When the comparison achieves a certain pre-determined degree of similarity, a "Termite Detected" message will be issued, otherwise a "No Termite Detected" message will be issued.  Furthermore, it will be appreciated by those skilled in the art that the acoustic pattern recognition system not only can be used to detect and identify termite infestation but can also be used to detect and identify other insect infestations by

simply replacing or supplementing the termite database library with another appropriate insect database library of interest.

Figs. 3-8 are graphs of termite sounds captured by the apparatus illustrated in Fig. 1 in various types of wood. Figs. 3, 4, and 5 show sounds analyzed in the frequency domain and Figs. 6, 7, and 8 show corresponding time domain waveforms in the form of .wav files. In the illustrated examples, it turns out to be more convenient to perform the analysis in the time domain, although it is also possible to use a frequency domain analysis. Additional examples and data concerning measured termite noises are included in Appendix A and in the above-cited sound recording authored by the present inventor and published by the U.S. Department of Agriculture on May 14, 2001, while data concerning different types of accelerometers is included in Appendix B.

The acoustic pattern recognition technique described above may be used to protect buildings or other structures from termite invasions even before any signs of termite infestation are visible through use of the thermal imaging camera 1 and acoustic sensors 11 (the term "structures" being intended to encompass natural as well as man-made victims of termite infestation, including trees), by

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permanently deploying an array of sensitive acoustic sensors on all major building structures such as trusses and joists, and by connecting the sensors to the central controller 12. Signals picked up by any sensor are passed through the electronic circuit which include a low noise amplifier and a band-pass filter arranged to exclude background noise and vibration signals below 100 hertz, and high frequency noise above 15 kilohertz. The processed signals are then converted into digital signals for processing by computers 13 and/or 16. The processing computer then tries to identify the newly received signals by comparing them with the pre-recorded data from insect data libraries 14 or 17. When the comparison achieves a certain pre-determined degree of similarity, a "termite invasion" warning signal may be issued to the home or building owner.

Fig. 9 shows an arrangement for evaluating potentially structurally damaged concealed area 18 according to the principles of the preferred embodiment of the invention. The illustrated arrangement employs a vibration-inducing device or shaker 19 and a laser vibrometer 20 for measuring the resulting vibration pattern, which depends on the integrity of the structure being analyzed. The shaker 19 induces a broadband frequency vibration in the building structure. Different construction and conditions of the

building structure respond differently to the induced vibration, causing reflections between areas of different impedance and resulting in a unique vibration pattern. The vibration patterns can then be easily picked up by the

5    laser vibrometer 20 and analyzed according to the principles set forth in herein incorporated U.S. Patent No. 6,081,481. Examples of frequency responses for identical input vibration patterns are illustrated in Figs. 12 and 13, for the corresponding structures illustrated in Figs.

10    10 and 11.

Another aspect of the preferred embodiment of the invention is the use of acoustic stimuli to change the behavior of termites. This aspect of the invention essentially involves exposing termites to various sounds

15    and determining the reaction of the termites to the sounds under various conditions. For example, certain sounds cause termites to feed, and others appears to function as a warning signal which causes the termites to stop feeding.

Fig. 14 shows an applied signal, which evokes the

20    response shown in Figs. 16 (scale) and 17 (amplified). Fig. 15 shows the response in the presence of carbon dioxide. Appendix C includes additional termite response data.

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The purpose of collecting data on termite responses to various noises is to alter the behavior of termites in ways that will facilitate their eradication without the need for widespread application of toxic chemicals. In addition to

5    recording audio responses by the termites, a video camera is used to record movements and other behaviors of the termites. Once a library of stimuli and responses is constructed, modification of the termite behavior simply involves playback of acoustic stimuli corresponding to the

10   desired response, and coupling of the played-back stimuli to the structure in which the termites have been detected.

Finally, according to an especially advantageous aspect of the preferred embodiment of the invention, the central computer 16 illustrated in Fig. 1 may be part of or

15   connected to a nationwide or even worldwide operations center that serves as a facility of data communications, data acquisition, data analysis, maintenance of sound libraries, continuous updating of sound library references, aggregation of recognition results, and aggregation of

20   inspection results. The resulting database or databases may include the above-mentioned libraries of termite sound and/or response data, as well as other types of termite data or information, for use by any individuals or entities interested in termite presence, behavior, movements, and

25   trends, as well as those specifically concerned with

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termite infestation and damage to structures. Access to the database may be by structure, species, or geography, or any other appropriate category or classification.

Having thus described a preferred embodiment of the invention in sufficient detail to enable those skilled in the art to make and use the invention, it will nevertheless be appreciated that numerous variations and modifications of the illustrated embodiment may be made without departing from the spirit of the invention, and it is intended that the invention not be limited by the above description or accompanying drawings, but that it be defined solely in accordance with the appended claims.

**I claim:**

1.  A system including an acoustic sensor for detecting the presence of termites concealed in a structure, wherein said acoustic sensor is an accelerometer having a bandwidth of at least 100 Hz to 15 kHz.

2.  A system including a sensor for detecting the presence of termites concealed in a structure, wherein said sensor is a passive laser doppler vibrometer.

3.  A system including an acoustic sensor for detecting the presence of termites concealed in a structure, further comprising a thermal imaging camera for scanning the structure before installation of the acoustic sensor in order to locate potential areas of termite infestation.

4.  A system as claimed in claim 3, wherein said thermal imaging camera includes pattern recognition capabilities.

5.  A method of detecting the presence of termites concealed in a structure, comprising the step of sensing noises made by the termites using an

accelerometer having a bandwidth of at least 100 Hz to
15 kHz.

6.  A method of detecting the presence of termites
    concealed in a structure, comprising the step of
    sensing noises made by the termites using a laser
    doppler vibrometer.

7.  A method for detecting the presence of termites
    concealed in a structure, comprising the step of using
    a thermal imaging camera to scan the structure before
    installation of an acoustic sensor in order to locate
    potential areas of termite infestation.

8.  A system for evaluating concealed structural damage
    caused by termites, comprising a vibration inducing
    device and an active laser doppler vibrometer for
    determining the extent of concealed structural damage
    caused by said termites.

9.  A method for evaluating concealed structural damage
    caused by termites, comprising the steps of inducing
    vibrations in the structure and using an active laser
    doppler vibrometer to determine the extent of
    concealed structural damage caused by said termites.

10. A system for modifying termite behavior, comprising a library of data concerning responses by termites to applied acoustic stimuli, and a device for applying a selected acoustic stimulus to a structure containing termites in order to invoke a desired response.

11. A method of modifying termite behavior, comprising the steps of referring to a library of data concerning responses by termites to applied acoustic stimuli, and applying a selected acoustic stimulus to a structure containing termites in order to invoke a desired response.

12. A method of collecting data and information concerning termites, comprising the steps of using acoustic sensors to detect termites in a structure and transmitting data collected by the sensors to a central operations center for inclusion in a central database of termite data and information.

## ABSTRACT OF THE DISCLOSURE

A method and system for detecting and controlling termites, and for evaluating structural damage caused by the termites, involves use of an acoustic detector in the form of an accelerometer or passive laser doppler vibrometer having a bandwidth of at least 100 Hz to 15 kHz to detect noises made by the termites, use of an active laser doppler vibrometer to assess structural damage, and playback of selected acoustic patterns to influence termite behavior. Information collected by the acoustic detector may be transmitted to a central operations center for inclusion in a comprehensive database of termite data and information.

NWB-S:\Producer\beu\Pending I...P\L\lee-termite-prov\appl-shell.wpd
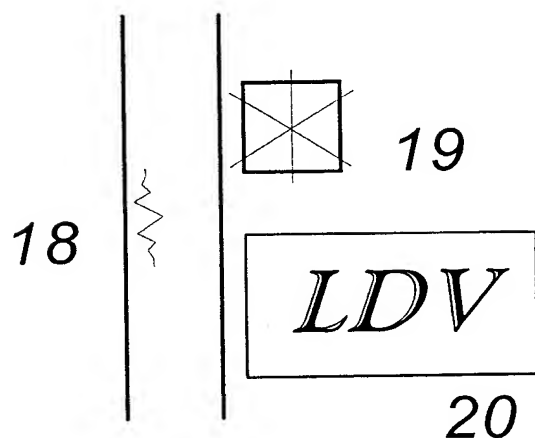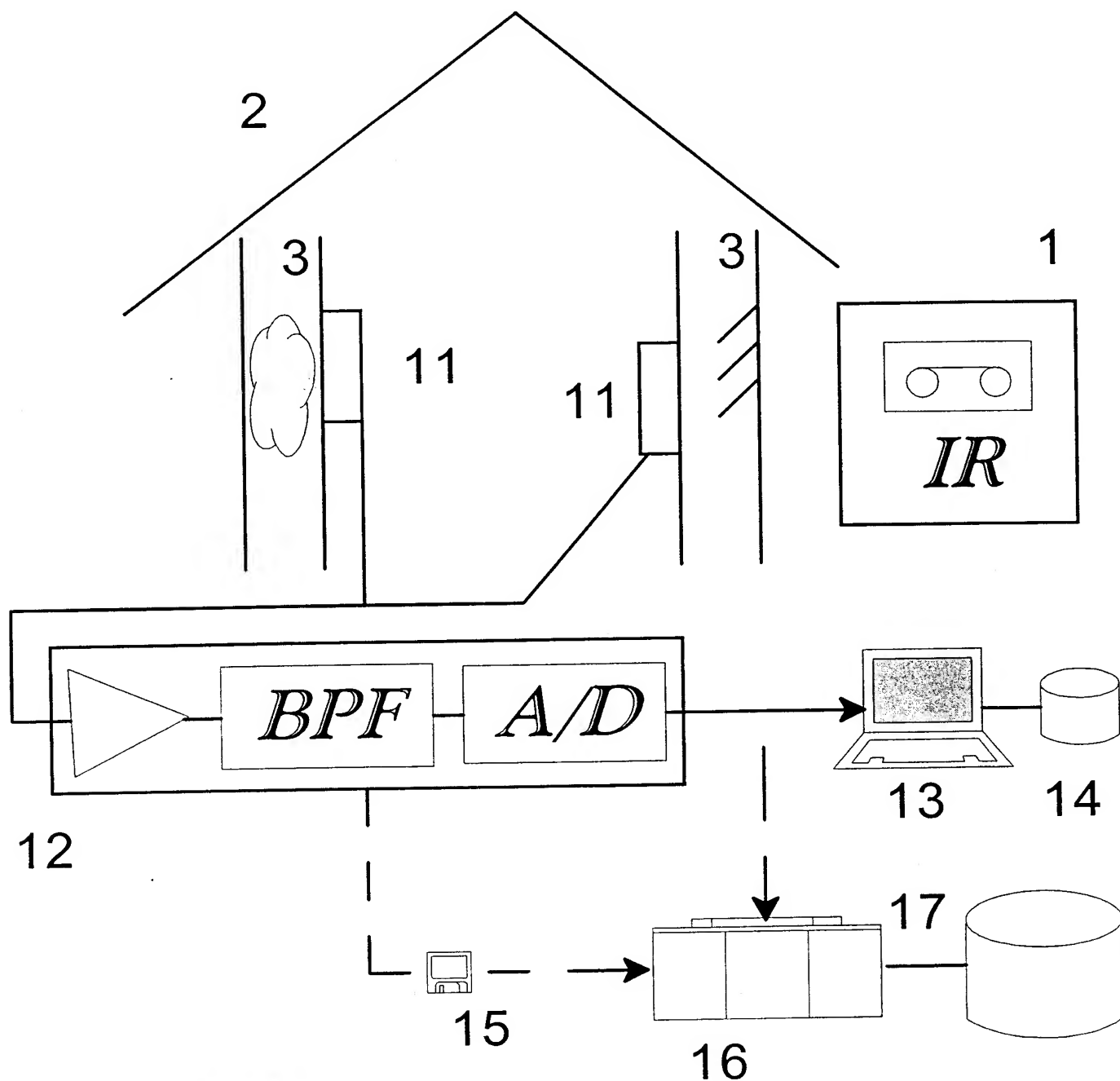
2

3

3

1

11

11

IR

BPF

A/D

13

14

12

15

16

17

Fig. 1

18

19

LDV

20

Fig. 9

Fig. 2

File Name: Sapelo_Island\pine_log_2_part_3.wav

Fig. 3

File name:new_orleans7_25_200treetree_formosan_2_part_1.wav

Amplitude

60

40

20

0

0    2500    5000    7500    10000    12500    15000
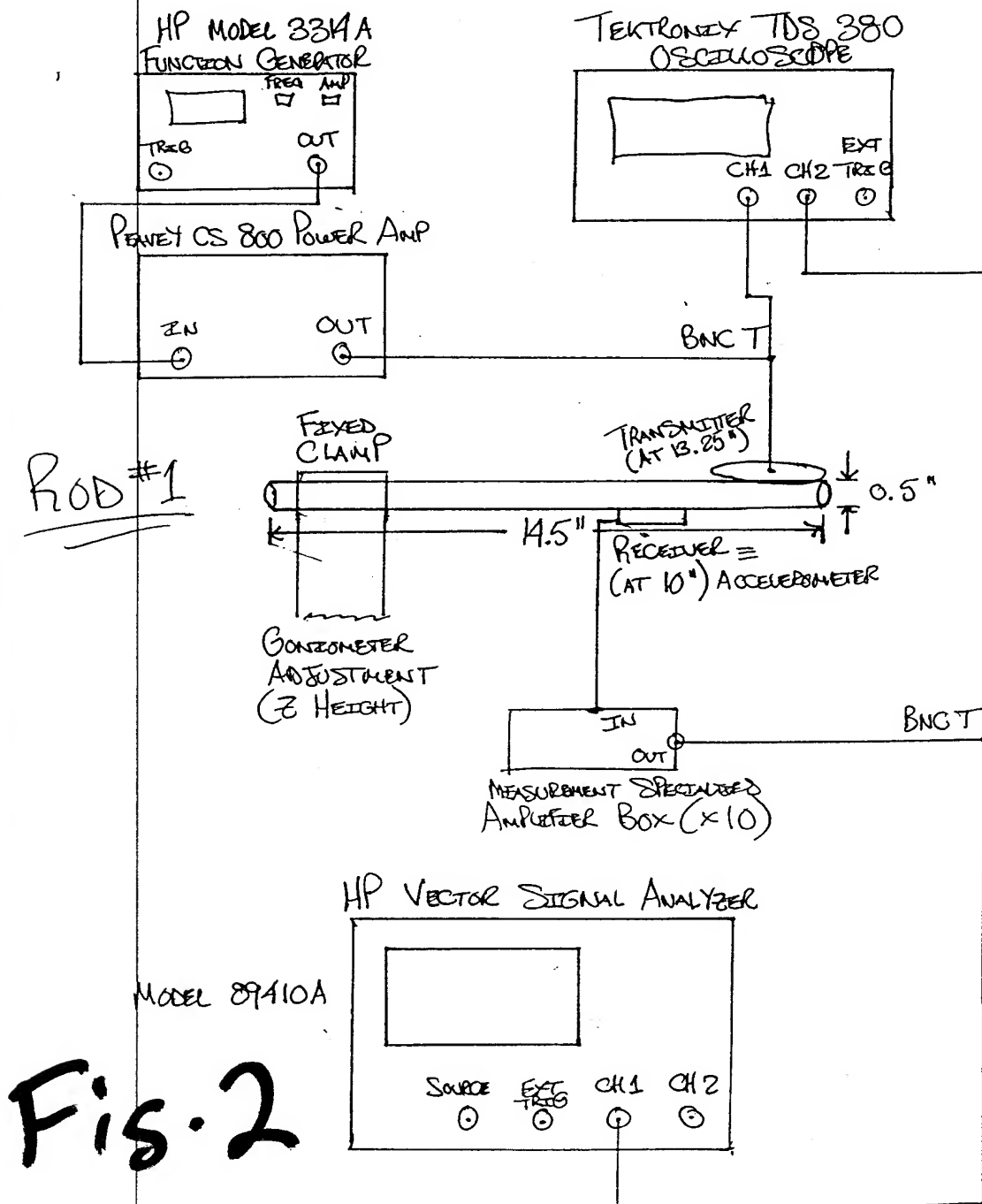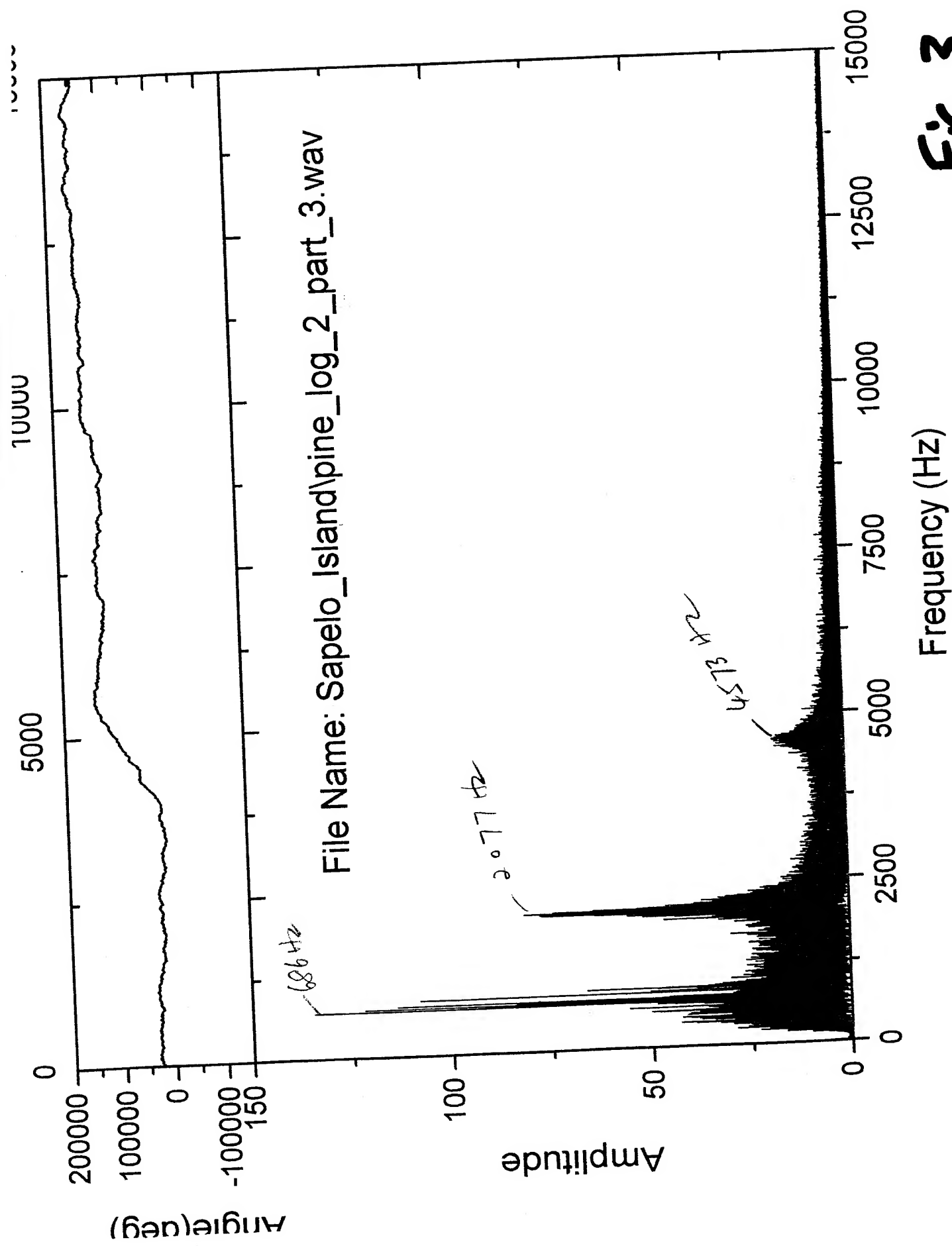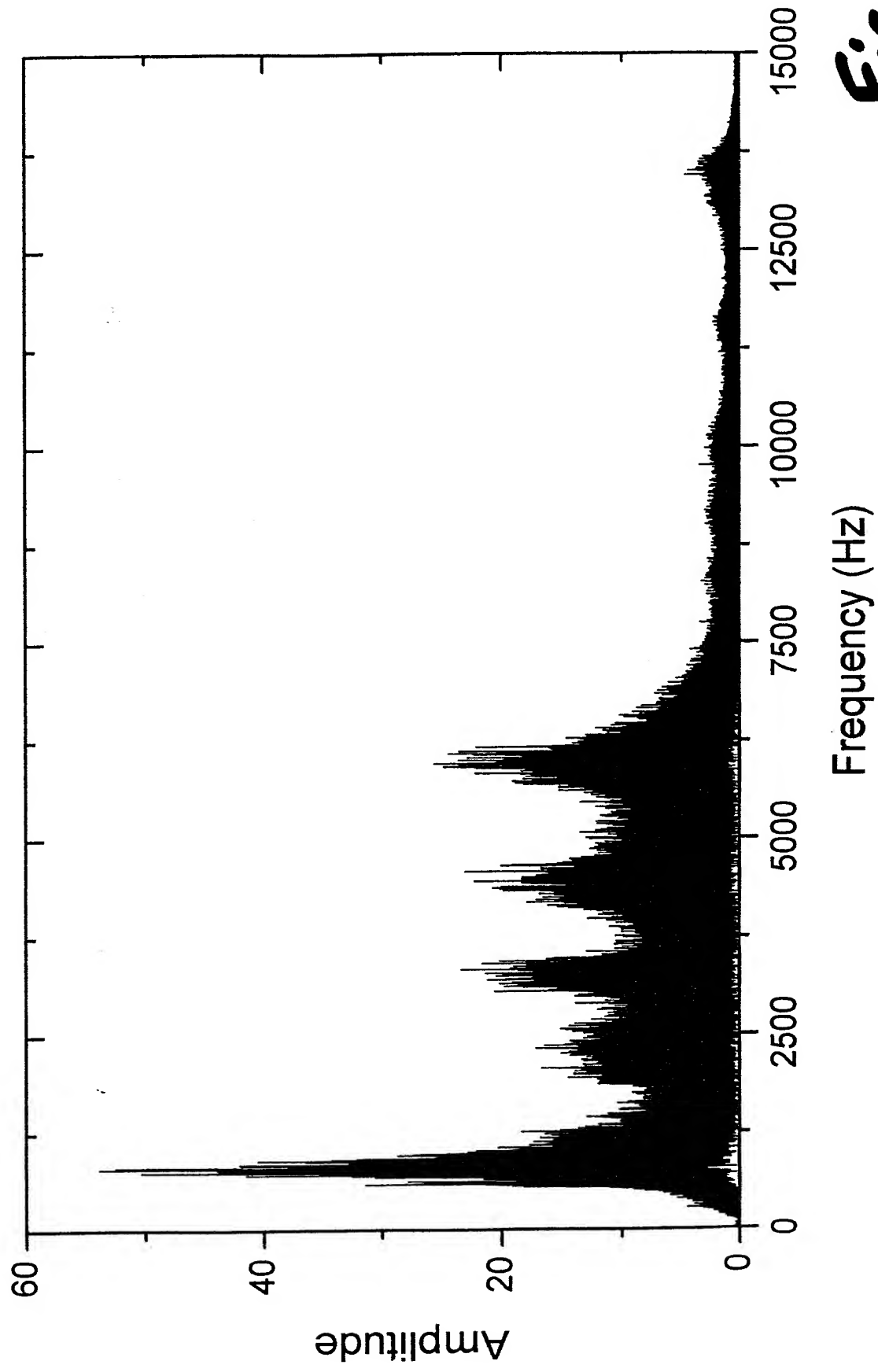
Frequency (Hz)

Fig 4

Termite sound (File name: retic_june_19_maybe_warning_afterdisturb_2_first_half.wav)
Frequency domain
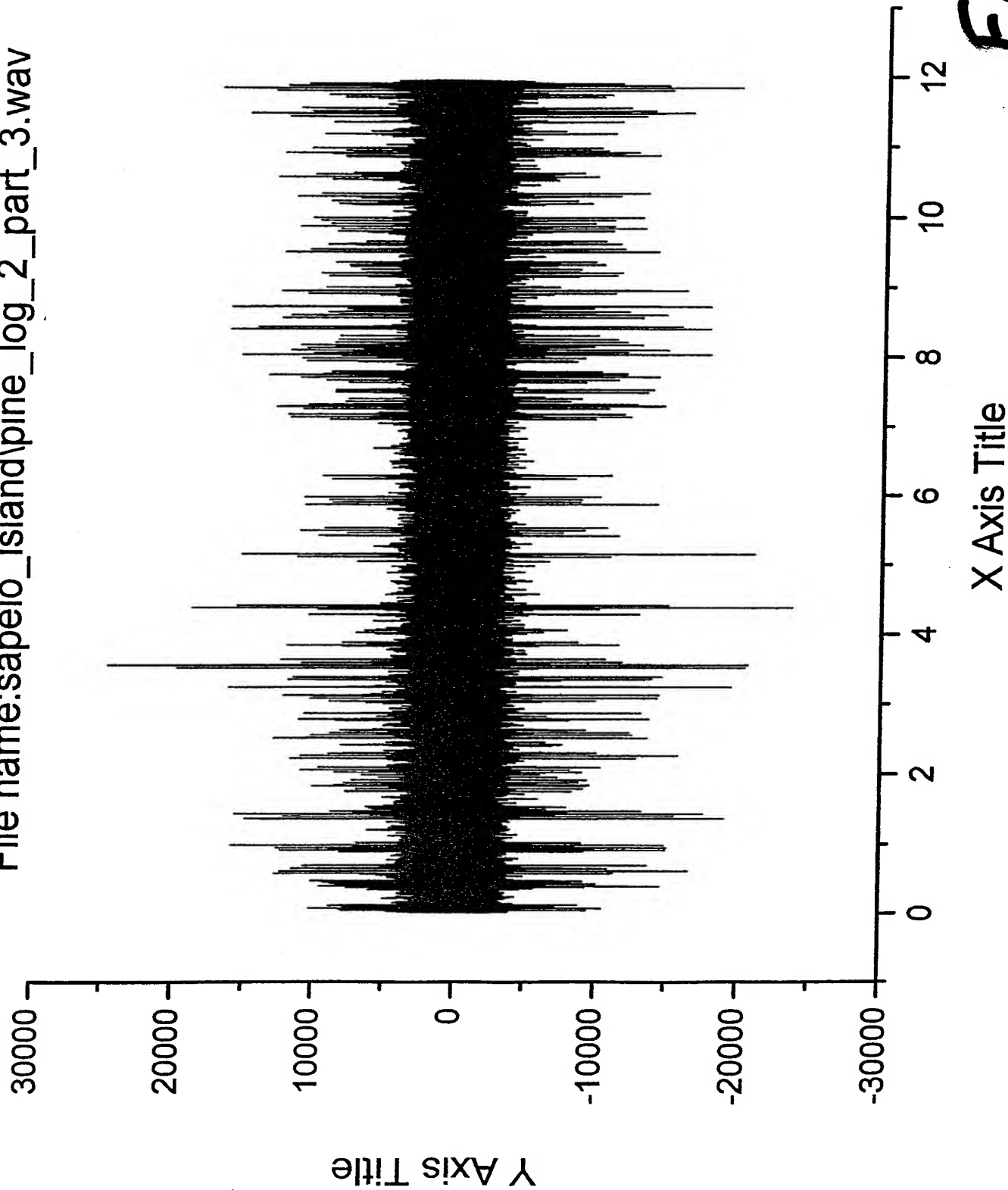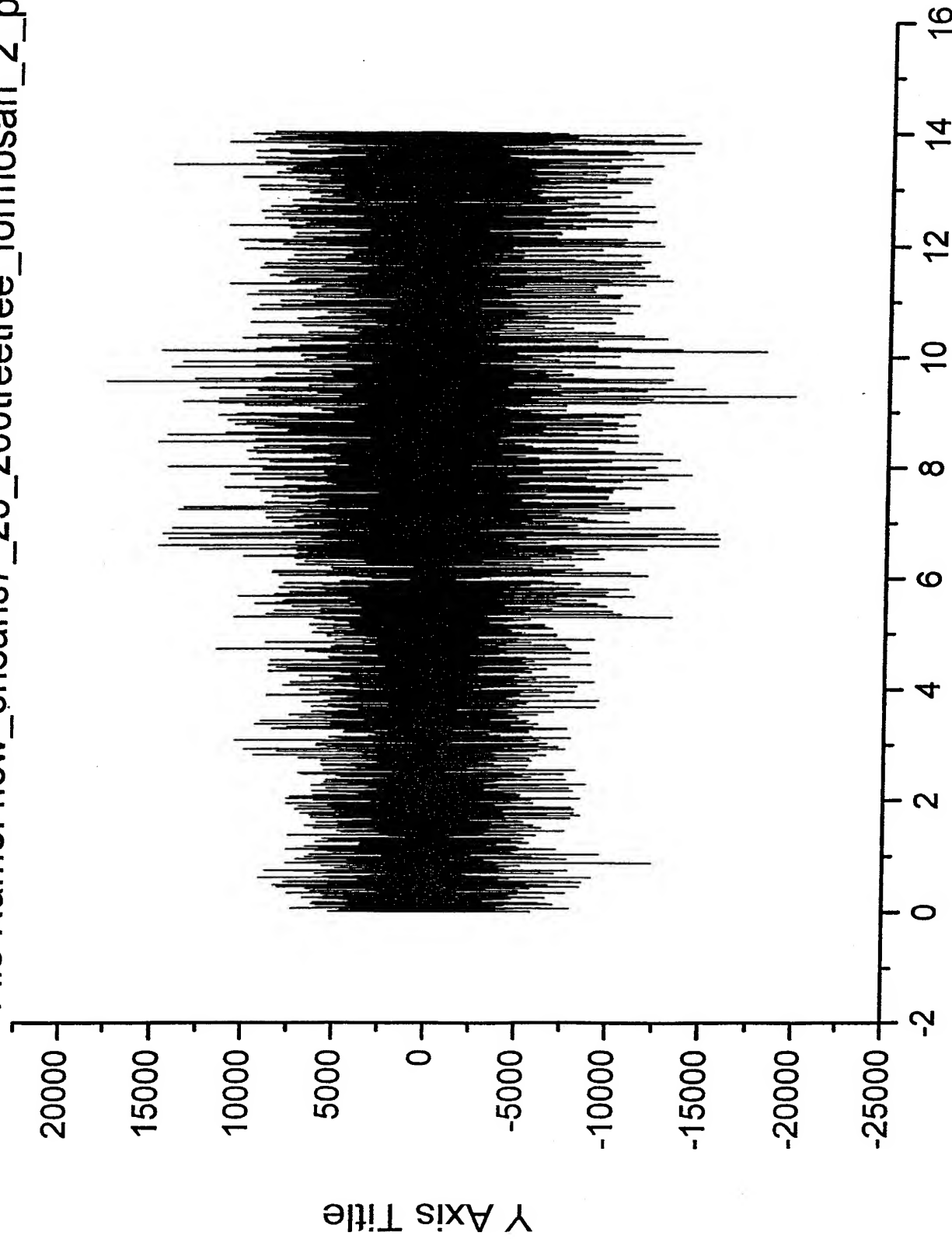


Fig 5

File name:sapelo_island\pine_log_2_part_3.wav

X Axis Title

Y Axis Title

30000  20000  10000  0  -10000  -20000  -30000

0  2  4  6  8  10  12

Fig 6

File Name: new_orleans7_25_200treetree_formosan_2_part_1.wav



X Axis Title

Y Axis Title

*Fig 7*

Fig. 8

afterdisturb-2 - maybe waning -
first half wav. g.
Time domain

X Axis Title

Y Axis Title

—— Data
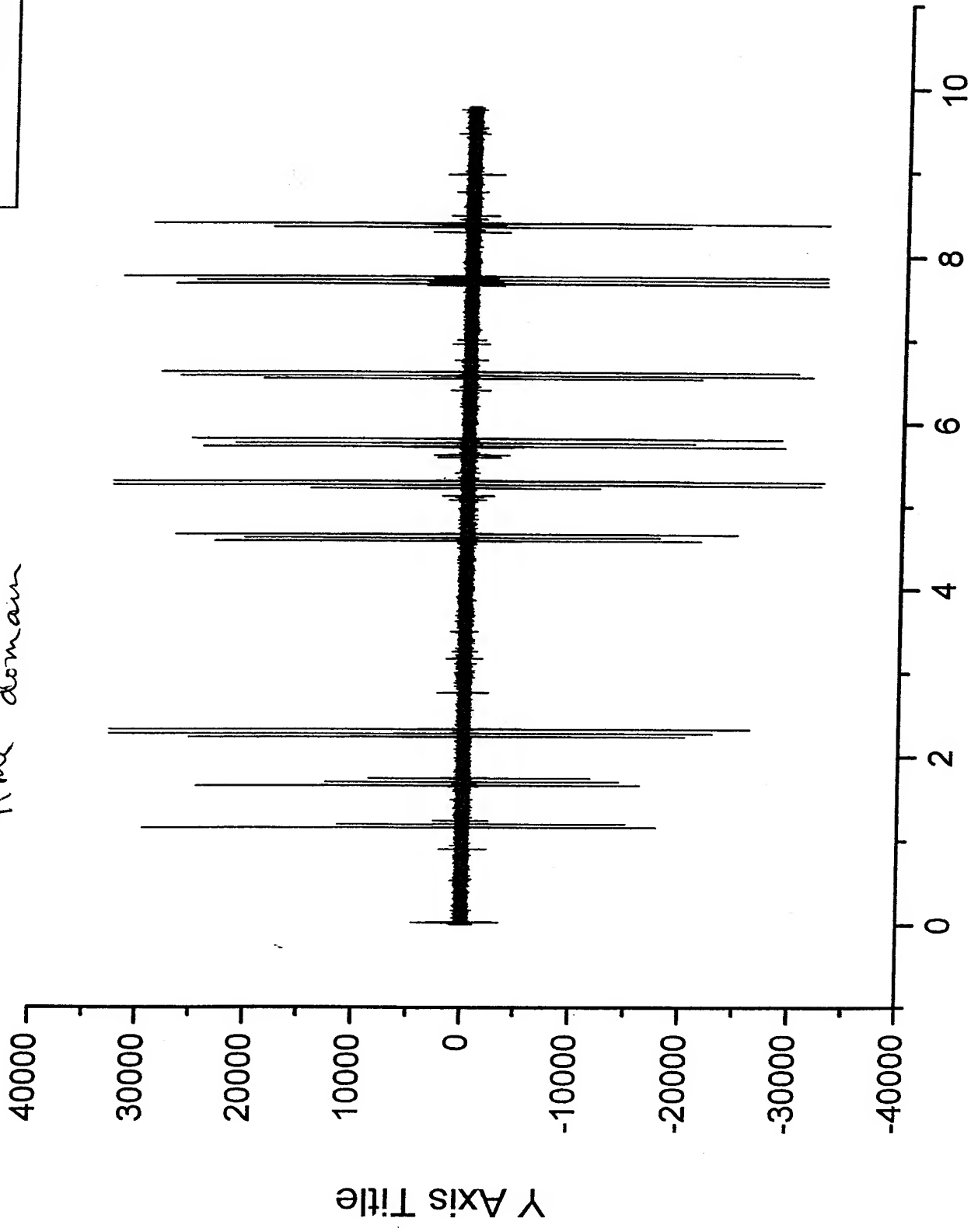
# Good and Damaged 2x4 Samples and Frequency responses

Free Free Freqres - Good Sample

Local/HP-IB 35565 Adrs: 11    Plot Adrs: 5
                Prnt Adrs: 6    Disk Adrs: 7
Date: 02-23-97  Time: 09:28:00 PM

A:D1 Freq Resp    X: 410    Y: 7.84965 dB

30
dB

10
dB
/DIV

dB Mag

                            AVG: 3

0Hz                Hz                800Hz

**Fig. 10**

**Fig. 13**

Free Free Freqres - Damaged Sample

Meas Data  Data A: D1    Data B: CH1 Time
(FFT)      Coord A: dB Mag  Coord B: Real
Date: 02-23-97  Time: 10:27:00 PM

A:D1 Freq Resp    X: 364    Y: 4.2100 dB

40
dB

10
dB
/DIV

dB Mag

-60
dB                          AVG: 3

0Hz                Hz                800Hz
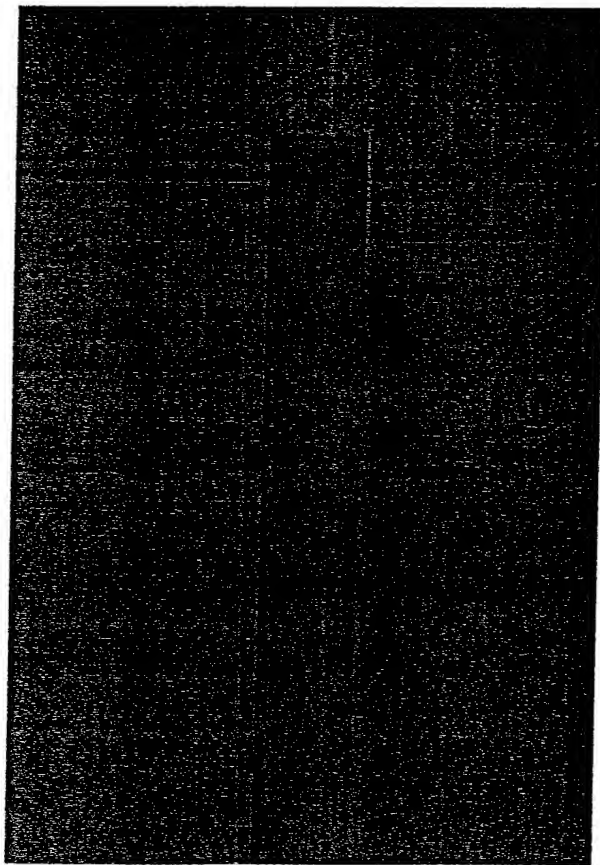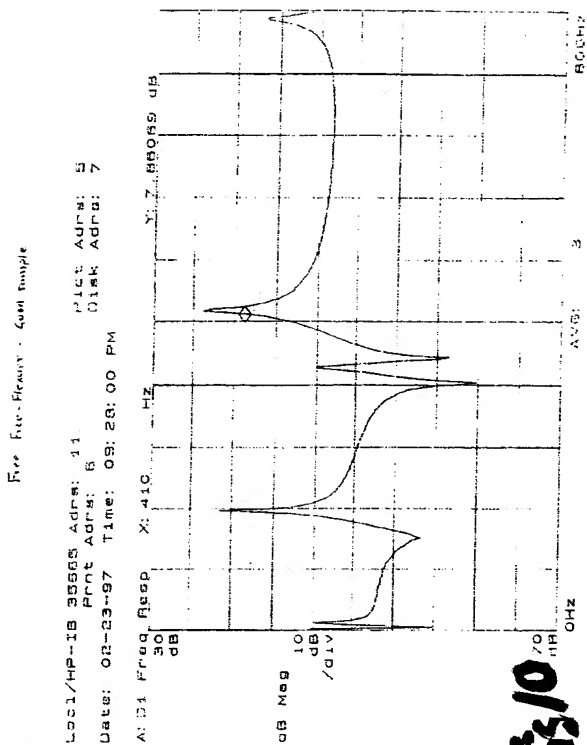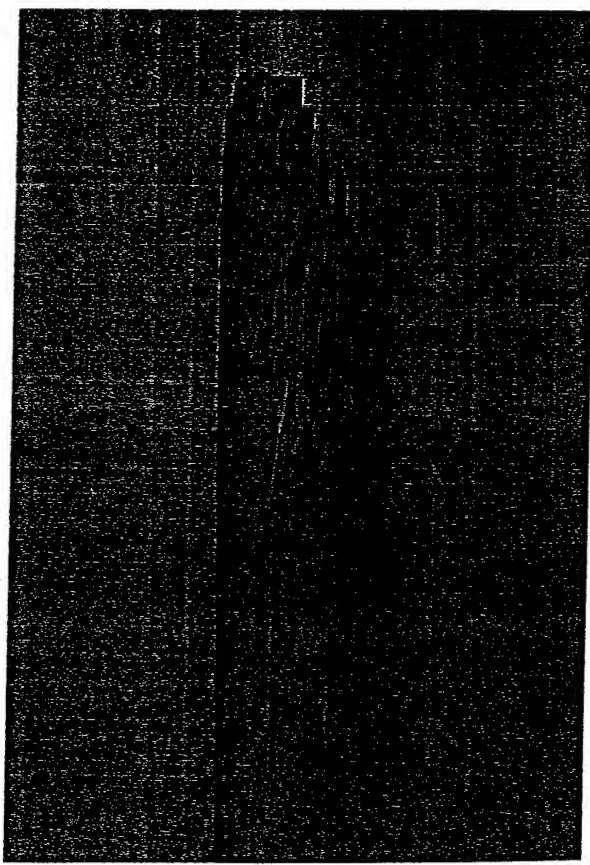
**Fig. 11**
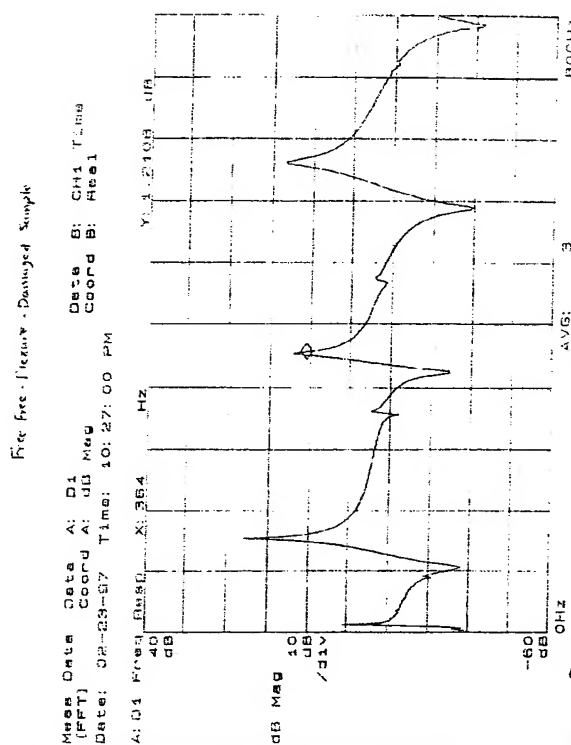
**Fig. 12**

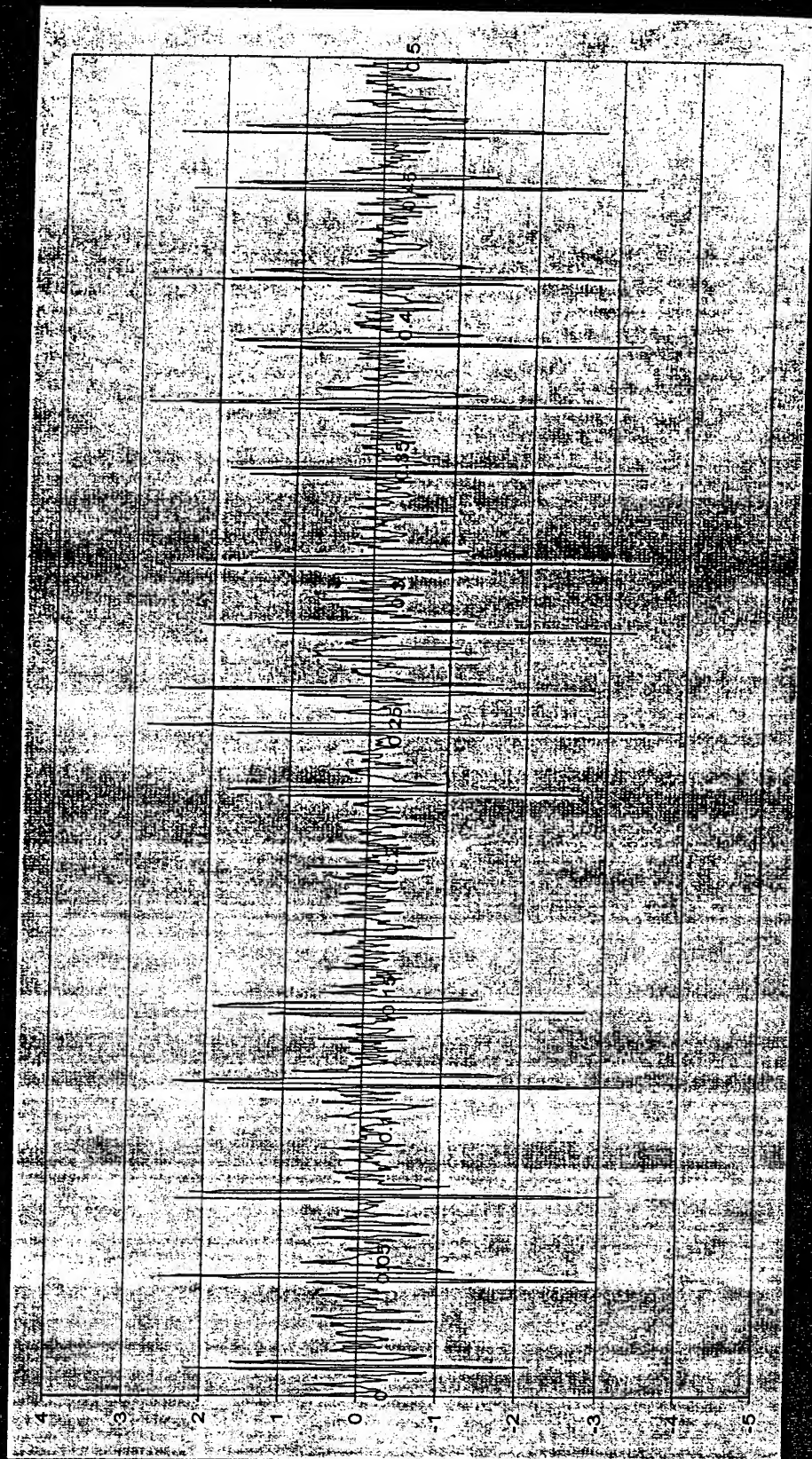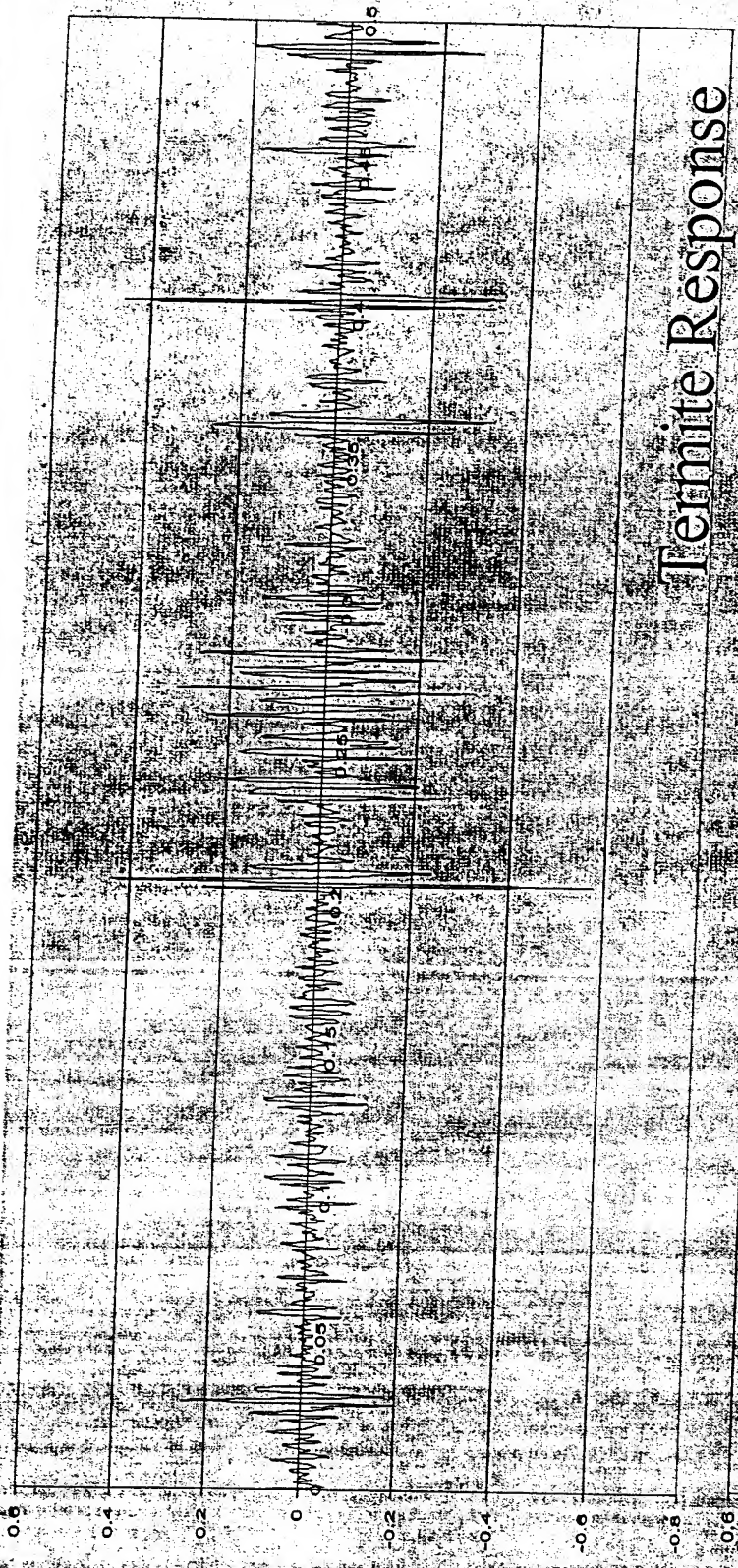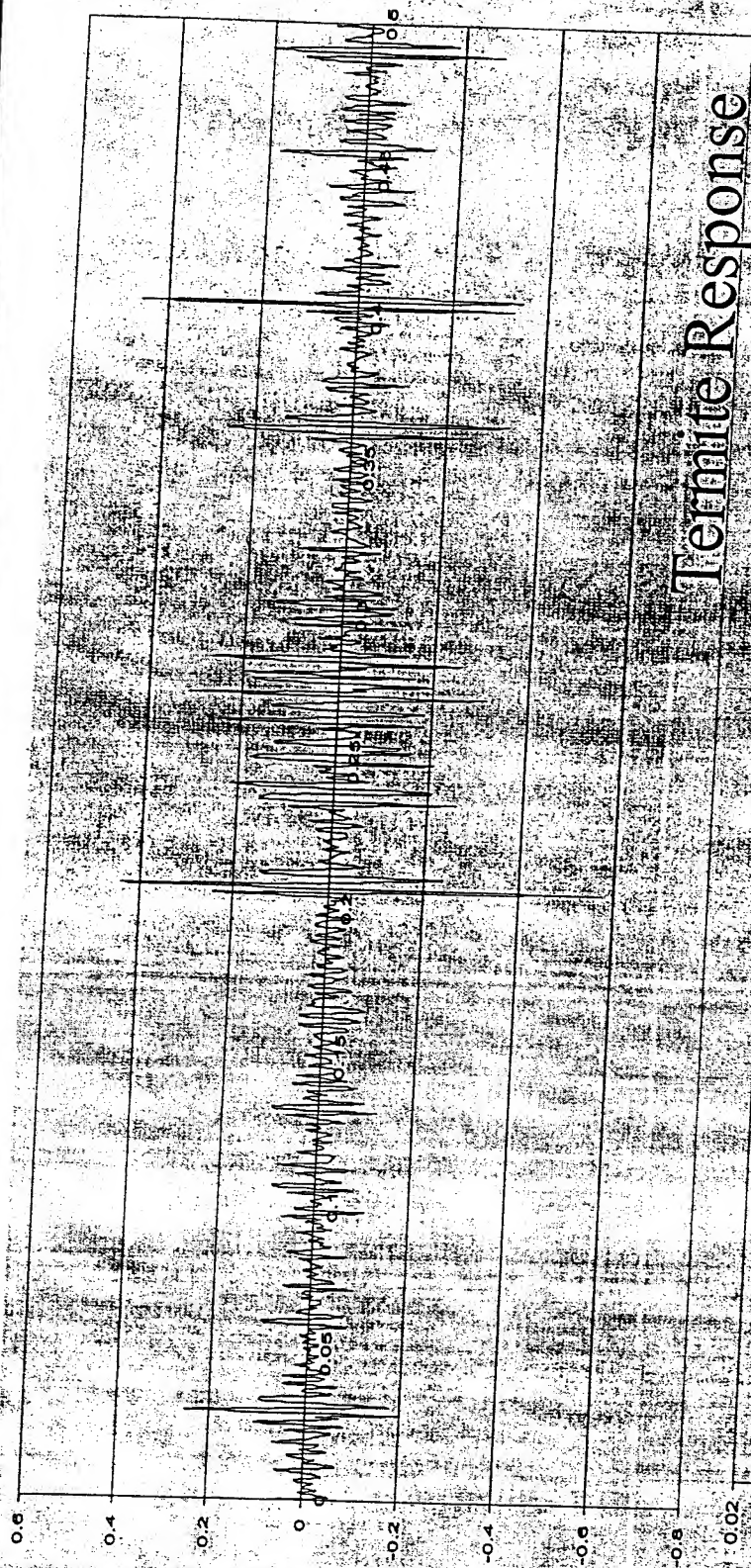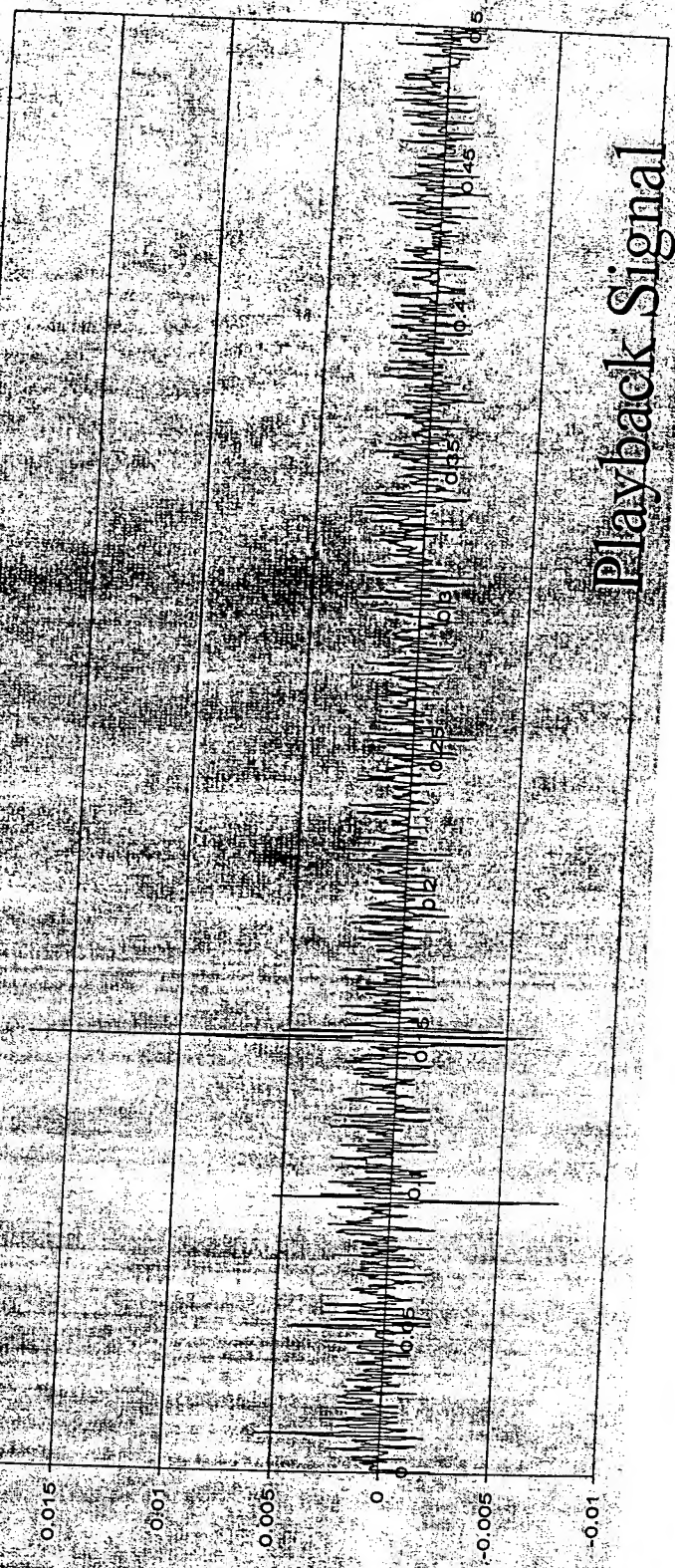Spontaneous Response
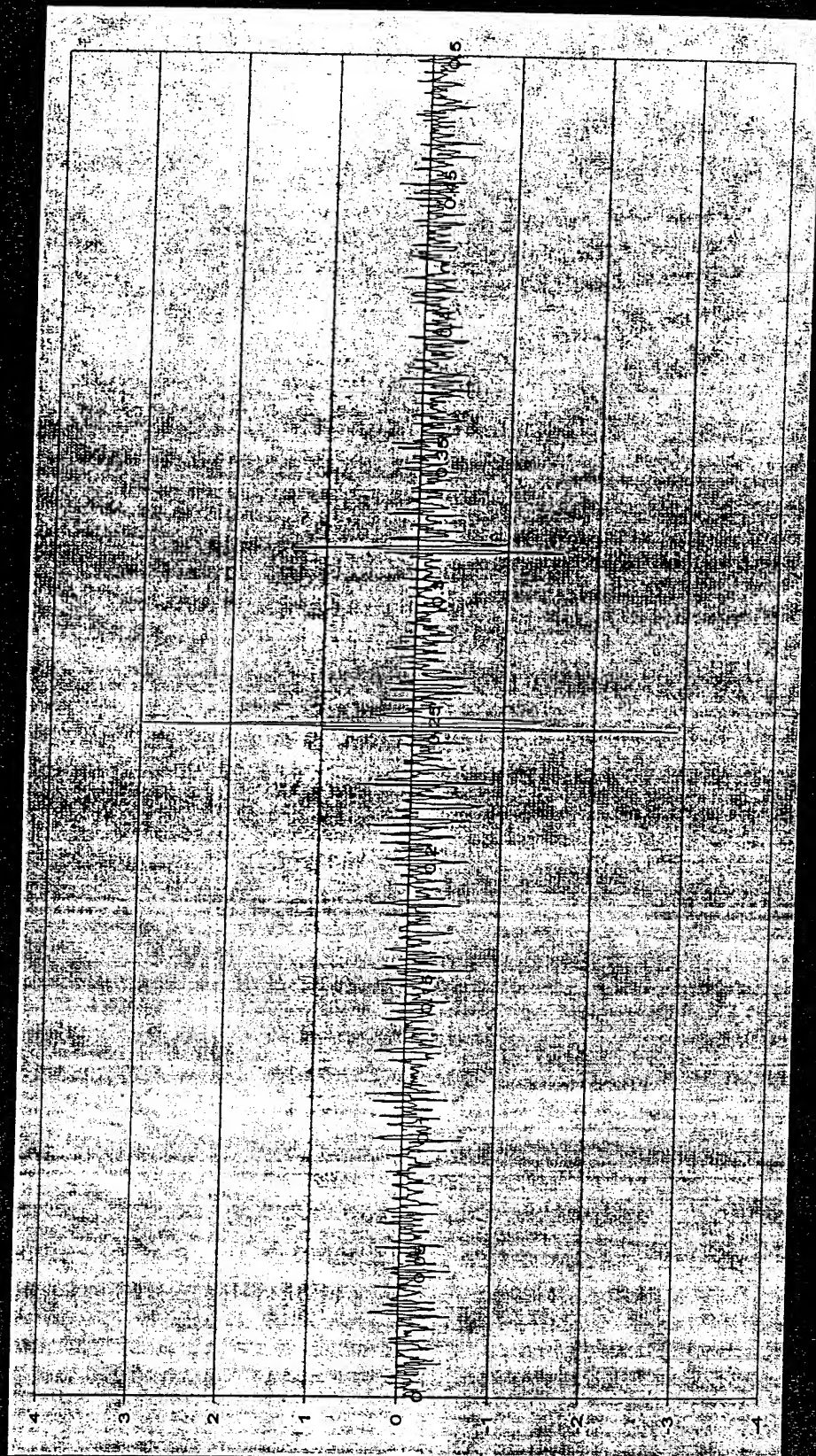


Fig. 14

Response from $CO_2$

Fig. 1

Termite Response

Playback Signal

FIG. 1

Termite Response

Playback Signal

Fig. 1